STUDIES RELATING TO SEEDING DEPLETED RANGE IN UNDISTURBED RESIDUES OF WEEDY VEGETATION KILLED BY HERBICIDES

by

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INTRODUCTION

Grasslands deteriorate as a result of mismanagement. When excessive removal of top growth is continued year after year, the desirable pasture plants are gradually eliminated by starvation and are gradually replaced by weeds. Weeds in pastures use moisture, nutrients, and light that might produce forage species of higher value. Although weeds when eaten may contribute to the diet of livestock, nevertheless plants classified as weeds usually are undesirable for numerous reasons. Many of them are low in productivity and palatability and are not relished by livestock. Some weeds cause undesirable flavors in dairy products; quite a few are poisonous or cause mechanical injury to the grazing animals. In addition, many of the weeds are annual plants greatly affected by seasonal adversities that result in wide fluctuations in production from season to season.

Available estimates of losses due to weeds indicate that the losses are great (9). Over a billion acres, or more than 50 percent of the land area in the United States, is grazed by livestock and about three-fourths of it is classified as open pasture. The United States Department of Agriculture has estimated that 240 million acres of these range and pasture lands are seriously infested with weeds and brush.

For more than 25 years experiments and field demonstrations throughout the United States of America have demonstrated the benefits of pasture renovation. But so far as range renovation is concerned there has not been much work done, probably because of several handicaps. Nevertheless the problem of range renovation is very urgent and needs far more study. The objective in pasture renovation, as in all new seedings, is to replace existing species in a poor pasture with more desirable pasture plants.

This involves as complete an eradication as is practically possible, of the present species of broad-leaved weeds and invading grasses, followed by the establishment from seed of high-producing forage mixtures. Disking, reseeding and the intelligent use of fertilizers on grazing lands have on every occasion increased the yields per acre from two to five times, depending upon the original condition of the sod. However, the abundance of poor pasture stand is witness that renovation has not been accepted for general use. This non-acceptance may be due to the necessity for too great an initial outlay or the tillage may be too laborious a task. The need, however, is self-evident for greater pasture production, for efficiency and greater profit on most livestock farms.

On level, easily managed soils a good seedbed can best be prepared with a plow, disk, and drag harrow. Successful seeding can then follow with conventional broadcast or hand seeding equipment. Such pastures are used in rotations with other crops on the farm. The problem of seedbed preparation on native ranges or pastures is difficult, since they are often steep and may also be stony and rough and hence can not be plowed for fear of erosion. Oftentimes it becomes physically impossible to till native ranges. According to Anderson (1), once a native pasture is allowed to deteriorate, its restoration may be a long and costly process, often involving years of protection from grazing and a great deal of tedious labor in weed control. The abundance of weeds in many rundown pastures made the eradication of the worthless vegetation the first step in the improvement of this land. Under such circumstances it is necessary to have a method of pasture and range renovation which would (i) eliminate all undesirable species present in the pasture which might otherwise afford competition with

the new seeding; (ii) eliminate the possibility of further deterioration of soil through erosion; (iii) permit adequate soil seed contact to encourage rapid germination and seedling development; and (iv) reduce or eliminate the need for tillage in seedbed preparation.

Methods employed during the past 25 years for improvement of weedy, overgrazed, and unproductive pastures have been that of repeated diskings or other surface cultivation. The surface tillage first kills the unwanted sod and leaves a mulch on these fields to deter erosion while the new seedlings are being established. This method, however, involves high cost.

Pearse (12) stated that "chemical control has been little used so far in preparing areas for reseeding. In part this is due to inadequate knowledge as to the proper use of chemical herbicides. Furthermore, many plants when killed and left in place still interfere with subsequent seeding. Chemical control appears to offer most promise for improving ranges".

The principle of using chemicals to reduce or eliminate the need for tillage in seedbed preparation, and at the same time to reduce the loss of soil through erosion, is thus a new method of pasture renovation which shows considerable promise for the future.

In order to serve the purposes of seedbed preparation, on pasture lands and native ranges, a chemical should have the following characteristics:

(1) It should be effective and dependable with respect to rapid and as nearly complete kill as possible of all the existing species.

(2) It should be economical on a per acre basis.

(3) It should dissipate itself rapidly from the soil and crop residue in such a manner as to permit reseeding shortly after chemical application.

(4) It should be easy to use at low gallonage with conventional equipment.

Work on the use of herbicides in pasture renovation is being carried out by New Jersey Agricultural Experiment Station for the past seven or eight years (22).

The purpose of this thesis is to present results of the experiments carried out under Kansas conditions in connection with seeding depleted range in undisturbed residues of weedy vegetation killed by herbicides. It is also the object to eliminate the need for tillage. The idea in the use of herbicides is to create a mulch of existing vegetation which otherwise would compete with new seedings. Further, the evenly distributed surface mulch of dead plant materials would function well for soil and water conservation. Such a mulch is attached to the soil surface and keeps the soil surface moist and cool. Elimination of tillage leaves a firm seedbed and old weed seeds are not stirred up from deeper soil.

REVIEW OF LITERATURE

In a 10-acre trial initiated in 1952 at Annandale, New Jersey, Sprague and Kates (22) obtained 5472, 5395 and 5969 pounds of dry forage per acre from the chemically renovated areas, disk renovated and plowed areas respectively. Each represented more than a 400 percent increase over the yields from untreated areas. The same relation was true during 1954. Considerable soil was lost from the plowed seedbed, whereas there was no evidence of erosion on areas protected by a surface mulch. The chemical renovation method consisted of using chemical such as TCA in place of repeated diskings in an attempt to reduce the large amount of costly tillage required. It was observed that dead sods responded far more readily to a disk than live sods. Following chemical treatment, two to three diskings were generally

sufficient to prepare an adequate seedbed compared to eight to twelve diskings in disk renovation method, for conventional broadcast or hand seeding.

In a similar trial at New Brunswick as reported by Sprague and Kates (22), disk renovated plots (11 diskings) yielded a total of 5024 pounds of dry forage per acre in 1953 and 5256 in 1954, while chemically renovated areas (two diskings) totaled 5032 and 5719 respectively. The International Harvester Pasture Renovater and John Deere Grassland Drill were used in successful seedings in New Jersey. These machines have been designed to place seed directly into the sod above a band of fertilizer and without tillage. Sprague (20) stated that disk renovated plots contained as high as 50 percent weedy grasses four years after seeding compared with 10 to 15 percent in adjacent plots renovated with a chemical. It appeared, therefore, that renovation with chemicals would last longer. In the preliminary trials in New Jersey it was observed that August and early September seedings following July application of the herbicides were established well. When seedings were made 30-31 days after TCA was applied, the fall seedings of rye and of bromegrass--ladino clover were killed due to insufficient rainfall. It is, therefore, necessary to tackle the problem of dissipation of chemical from the soil. Reseeding within a reasonable length of time is also essential. Aside from the loss of use of grazing land, too great a delay will permit weed seeds in the soil to germinate and a new weed problem will be presented. Kates et al. (8) stated that in 1949 herbicides were tried as a means of replacing most of the tillage requirements. Endothal (sodium 3, 6-endoxohexhydropphthalate), Dow General (dinitro-ortho-sec-butylphenol), TCA (sodium trichloroacetate) and sodium arsenite were compared for killing established sods. TCA (sodium salt) at 25 pounds per acre proved most effective.

Where broad-leaf weeds were present 1/2 pound 2,4-D was added. Regrowth of indigenous grasses was negligible, the surface mulch was effective in deterring erosion, and a new seeding made 30 days after spraying grew well when adequately fertilized. However, its corrosive nature, dependence on rain for dissipation from the soil, and cost per acre ($12 to $15) made TCA impractical for wide acceptance. Phenyl dimethylurea, CMU (3-p-chlorophenyl-1, 1-di-methylurea), and CIPC (isopropyl-N-3-chlorophenyl-carbamate) were tested during 1952 and 1953 but were unsatisfactory due either to incomplete kill of existing grasses or too long persistence of toxic concentrations in the soil. Results with chemicals in the above tests indicated that a satisfactory chemical must translocate readily downward from treated foliage to underground vegetatively reproductive parts. This characteristic is necessary to eliminate rainfall, which is not predictable, as a controlling factor. Dalapon (sodium a, a-dichloropropionate) and amino triazole (3-amino-1, 2 4-triazole) were reported to be such chemicals. Dalapon was first tested in New Jersey in July 1953 at rates 2 1/2, 5, 7 1/2, 10, 15, and 20 pounds per acre of active ingredient on sod consisting of 70 percent Kentucky bluegrass and 30 percent smooth brome. In this trial 2 1/2 pounds per acre of dalapon accomplished only about 50 percent kill and recovery was complete within a season. The higher rates of 5, 7 1/2, 10, 15, and 20 pounds per acre killed the entire sod within six weeks. The entire plot area was disked and seeded to rye and bromegrass in September 1953. The seeded species grew well on plots which had previously received 5, 7 1/2, and 10-pound treatments. In plots treated with 15 and 20 pounds per acre all seedlings were killed. Rainfall and soil moisture were limiting. It was observed in further tests that Dalapon at 6 to 8 pounds per acre and amino triozole

at 4 to 6 pounds per acre brought about the desired kill of old grass sods without serious danger to new seeding. Dr. J. B. Washo in Pennsylvania, as quoted by Sprague (21), has compared a number of methods of seedbed preparation including TCA at 50 pounds per acre. Most have given comparable yields but the number of required tillage operations to prepare a satisfactory seedbed have been reduced only from ten to seven through the use of the herbicide. Dr. R. A. Peters, as quoted by Sprague (21), found dalapon to be the best against bentgrasses and bluegrasses when applied in late summer. In their recent paper Sprague et al. (23) stated that weed seedlings have been more troublesome in the August seedings than in those made in late winter or spring. Cacodylic acid applied the same day as seeding was helpful in solving this problem. Robbins et al. (14) stated that residual effects from 2,4-D application are common in the West because soils may be dry during the hot summer and cool during the rainy season. Residues that disappear in a month or six weeks under eastern conditions have been known to persist for six months in arid regions. In most infestations of perennial weeds, seeds persist in the soil for years after the original stand has been killed. Reinfestation by seedlings may occur at any time when conditions are favorable.

In studying the residual effects of dalapon on crops, Rogers and Hart (15) applied dalapon to johnsongrass in early June with application rates of 10, 20 and 30 pounds per acre. Three weeks later soybeans and sweet corn were planted. On July 15 the plants were inspected and found to exhibit injury in varying degrees. In a similar study Anderson (3) planted oats, corn, and forage sorghum in plots one year after application of 40 pounds of dalapon per acre. He reported that the crops made excellent growth.

Appleby (4) found that corn, grain, sorghum, and sudangrass planted three weeks following application of dalapon at 25 pounds per acre made excellent growth. Wheat, barley, and oats made satisfactory growth later in the season. Alfalfa and soybean results were inconclusive. Freeman (7) found that three weekly sprayings of three to seven pounds of dalapon per acre followed in one week by plowing gave 99 percent control of johnsongrass without apparent injury to wheat sown four weeks after the last spraying. Parsons (11) applied 7 and 14 pounds of dalapon per acre to bluegrass sod, disked the area, and seeded birdsfoot trefoil (Lotus corniculatus) at various intervals after application, the first seeding being made within five days. He found no evidence of toxicity from the highest rate of application combined with the shortest interval of seeding. Buchholtz and Peterson (5) suggested that crops be planted no sooner than three weeks after plowing soil recently treated with dalapon. Southwick (25) reported that when dalapon is mixed with highly active contact herbicides such as 2,4-D, its effectiveness is reduced. Klingman et al. (10) stated that dalapon apparently possesses less residual toxicity than TCA, but further research is needed to determine the rate of disappearance of the herbicide from the soil. Davidson and Slife (6) stated that properly timed sprays of dalapon at concentrations ranging from 4 to 10 pounds per acre may be used on established stands of alfalfa. Vengris (27) found dalapon at 10 pounds and 15 pounds per acre to be promising in the destruction of Poa pratensis, P. trivialis, Pleum pratense and Agrostis spp. Peters and Kerkin (13) reported that dalapon gave excellent control of foxtail (Setaria spp.) and crabgrass (Digitaria spp.) in early postemergence applications on alfalfa and birdsfoot trefoil. Scholl and Staniforth (17) found that 4 pounds of dalapon per acre gave excellent

control of grassy weeds in young birdsfoot trefoil. There was no appreciable injury to the legume from applications upto 12 pounds per acre. However, other herbicides were needed to control broad-leaved weeds. Erbon is a non-selective herbicide for controlling both grasses and broadleaved weeds. It has given excellent control of johnsongrass when applied at the rate of 160 pounds per acre (2), (26), (29). Warden and Davidson (38) found that seasonal control of average grass and broad-leaf vegetation required 120-160 pounds per acre of erbon. They further stated that the species less readily controlled by erbon included Circium arvense, Plantago spp., and Rumex spp. In studying the residual effects of erbon on crop growth, Anderson (3) planted oats, corn, and forage sorghum on plots that had been treated with 160 pounds of erbon per acre the previous year. He reported that these crops made excellent growth. Appleby (4) observed no satisfactory growth of corn, sorghum, and sudangrass planted three weeks following the application of erbon at 80 pounds per acre. Swezey (26) stated that residual control of encroaching vegetation and the prevention of seedling germination by erbon residues in the soil can be expected for several months following application. Klingman and McCarty (9) reported that mowing in either June or July for three years (1951-53) reduced stands of perennial broad-leaved weeds about 35 percent. One pound of 2,4-D ester per acre applied on the same dates reduced stands 70 percent, while plowing and seeding grasses (plus 2,4-D) reduced perennial weed stands 89 to 94 percent. The 2,4-D was clearly superior to mowing for perennial weed control. Plowing and reseeding (plus 2,4-D) reduced annual weeds 62 to 95 percent. Ironweed was reduced in stand 53 percent by mowing in mid June for three seasons but the 2,4-D treatments gave 93 and 76 percent reduction

for the June and July dates of application, respectively. Plots plowed and seeded to grasses (plus 2,4-D) had over 98 percent control of ironweed. Applications of 2,4-D were greatly superior to mowing for control of ironweed and false boneset. The 1958 research summaries of the North Central Weed Control Conference have mentioned that 2, 3, 6-Trichloro-benzoic acid (2, 3, 6-TBA) was used both as a foliage and soil application for vegetation control. Leafy spurge and Russian knapweed can be controlled with a soil residual application of 20 to 40 pounds per acre. Lower rates of 1 to 4 pounds per acre in corn, under certain conditions, have given fair weed control without injury. As a non-selective foliage spray, many annual weeds have been controlled with 10 pounds per acre. When four pounds acid equivalent per acre of 2,3,6-TBA were applied to knapweed or leafy spurge during May and the area was plowed ten days later and planted to corn that was checked and cultivated three times, 80 to 90 percent of the knapweed and leafy spurge were eliminated. In one case out of five, the corn was injured (16). In 1958, chemicals that gave excellent control of bur ragweed two years after fall treatment were 2,3,6-TBA at 40 and 60 pounds per acre, erbon at 160 pounds per acre etc., (16). Two pounds per acre of 2,3,6-TBA was found specific for red sorrel (16) in turfs. The 2,3,6-TBA at 4 pounds of acid in 100 gallons of water used as a foliage spray has shown promise for the control of persimmon (16).

MATERIALS AND METHODS

Field Experiments

Weedy native pastures were selected at two locations, one near Lebo, Kansas, about 100 miles southeast of Manhattan and the other about seven

miles northwest of Manhattan. Throughout this thesis these locations will be mentioned as 'Lebo' and 'Manhattan'. The two locations had different botanical compositions as will be seen from Tables 2 through 5. At Lebo, the soil was rather fine textured and deep, whereas at Manhattan the soil was poor and shallow with limestone rock in the surface at some places. The herbicidal treatments employed together with rates of applications are given in the following table.

Table 1. List of herbicides showing the rates of application.

Chemical	Rate	Plot numbers
A 2,4-D L. V. ester	2 lbs/acre	8, 12, 21, 34
B 2,4-D L. V. ester	4 lbs/acre	3, 17, 24, 37
C 2,4-D + dalapon	2 lbs + 8 lbs/acre	10, 14, 27, 32
D 2,4-D + dalapon	4 lbs + 4 lbs/acre	6, 18, 30, 40
E Erbon	1/2 lb per square rod	1, 11, 23, 35
F Erbon	1 lb per square rod	4, 16, 29, 31
G T.B.A. (2,3,6-TBA)	8 lbs. per acre	7, 19, 26, 38
H T.B.A. (2,3,6-TBA)	16 lbs per acre	9, 13, 22, 33
I Check		2, 20, 28, 39
J Check		5, 15, 25, 36

The selection of weedicides was made in consultation with Dr. L. E. Anderson, Assistant Professor of Agronomy (weeds), Kansas State College, of Agriculture and Applied Science, Manhattan. The layout of the experiment was a randomized block design with 10 treatments and 4 replications as shown in Fig. 1. Treatments were applied on June 10, and June 18, at Lebo

F 31	C 32	H 33	A 34	E 35	J 36	B 37	G 38	I 39	D 40	Replication IV
A 21	H 22	E 23	B 24	J 25	G 26	C 27	I 28	F 29	D 30	Replication III
E 11	A 12	H 13	C 14	J 15	F 16	B 17	D 18	A 19	I 20	Replication II
E 1	I 2	B 3	F 4	J 5	D 6	G 7	A 8	F 9	C 10	Replication I

Fig. 1. Layout of the grass experiments at Lebo and Manhattan, 1958-59.

and Manhattan, respectively. Water was used as carrier in all formulations. Each plot was 51' long and 10' wide. Treatment was applied to 51' x 8' area of each plot so that untreated, 2-foot strip could be left between adjacent plots to prevent accidental overlapping. Following the herbicidal treatments, botanical composition of each individual plot was determined by the line transect method. Counts of the number of plants of each species and whether killed, damaged, or unaffected, were recorded on August 25, 1958. Flats were filled, one from each plot, for greenhouse study. Each flat included a representative sample of the upper three inches of soil from a plot. The flats were numbered to correspond to the plot numbers.

Three quadrats each of $\frac{1}{10,000}$ acre or 4.356 square feet were clipped for yield tests from each plot. Green and killed material from each quadrat were put in separate paper bags for drying in an oven to constant, moisture-free weight. At Lebo, due to subsequent growth of crabgrass and Setaria, quadrat clipping was stopped after taking cuts from 10 plots. The cuts from quadrats were made in order to determine the efficacy of the herbicide, the principal assumption being that the more effective the kill of the herbage the less would be the weight of the dead residue cut from each quadrat, compared to that of quadrats cut from check plots.

Experimental plots located at Manhattan were seeded on October 13, 1958. However, due to total absence of rain following the seeding, the seeds remained in soil without germination. Consequently germination counts under field conditions could not be taken.

Greenhouse Experiments

Well cleaned seeds of 11 species of grasses comprising 1. timothy,

2. orchardgrass, 3. Kentucky 31 tall fescue, 4. western wheatgrass, 5. Southland smooth brome, 6. reed canarygrass, 7. intermediate wheatgrass, 8. big bluestem, 9. indiangrass, 10. sand lovegrass and 11. sand bluestem were germinated in petri dishes using 0.1 percent solution of 'Captan-75' seed protectant to prevent growth of fungi. Three replications, that is, three petri dishes each containing 100 seeds of each of the above mentioned 11 species were tested for germination. Due to comparatively high temperatures, 90-95° F during July, dishes were kept in cold chambers maintained at about 65° F. Observations were made for 15 days, and the averages for seed germinated were determined.

Flats containing representative samples of soil from two locations, viz. Lebo and Manhattan, were brought and kept in the greenhouse for study of residual effect of the chemical left in the soil on the germination ability of grass seeds of various species. Soil in each flat was sifted to remove shoots and roots of the dead material. Each flat was 2' long and 1' wide. One row of each of the 11 species was sown in each flat. Exact number of seeds were counted, based on the germination studies, in an attempt to give 50 seedlings per foot row. Seeds were sown in rows about 2" apart by means of special sowing device. Sowings were done on October 16, 17, 18, and 19, 1958. Counts on resulting seedlings and the average height of each row of plants in a flat were recorded on the 16th through 19th of November 1958. For taking average height, five randomly selected plants were measured to represent the row. It was assumed that if the number of seedlings of a species in any flat happened to be smaller than the number of plants of the corresponding species in check flat, the deficit was to be ascribed to the residual effect of the herbicide left in the soil in such

flat. It was also assumed that the residual effect of herbicides could also be manifested in the slow growth of plants resulting in short-statured plants. Seed packets containing seeds of different grass species were prepared for sowing flats and plots, the seed rate being based on germination tests.

Data were analyzed statistically wherever possible by making use of chi-square tests, analysis of variance, and least significant differences (18).

In computing analysis of variance for the results presented in Table 6 percentage figures of dry (killed by herbicides) matter compared to the total material clipped per quadrat, were used. Since most of the quadrats contained green and dry (killed by herbicides) material in various proportions, it was convenient to use percentage figures of dry (killed) matter compared to the total vegetation clipped per quadrat.

EXPERIMENTAL RESULTS

Botanical Composition of the Experimental Plots

Data regarding percentage of different classes of plants and degree of injury following herbicidal treatment at the two locations Manhattan and Lebo, are presented in Tables 2 and 4. Averages for the number of broadleaf weeds of key species, after herbicidal treatments, are presented in Tables 3 and 5 for the two locations, respectively.

At Manhattan (Table 2) the perennial grasses were chiefly big bluestem (*Andropogon gerardi*), sideoats grama (*Bouteloua curtipendula*), buffalograss (*Buchloe dactyloides*) and small amounts of little bluestem (*Andropogon scoparius*) and hairy grama (*Bouteloua hirsuta*). Broadleaf species (Table 3)

Table 2. Botanical composition of the experimental plots at Manhattan as determined by line transect method. The data are arranged treatmentwise (herbicidal treatments).

	Percentage composition																				
	Perennial grasses				Annual grasses				Perennial forbs				Annual and biennial forbs				Carex and Juncus				Total vegetation
Tr.[@]	K*	D	H	% of vegn.	K	D	H	% of vegn.	K	D	H	% of vegn.	K	D	H	% of vegn.	K	D	H	% of vegn.	%
A	3.0	4.0	91.0	98.0	0.0	0.0	0.4	0.4	0.3	0.3	0.6	1.2	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0	100
B	6.0	7.0	85.0	98.0	0.0	0.0	0.0	0.0	0.3	0.4	0.4	1.1	0.6	0.0	0.3	0.9	0.0	0.0	0.0	0.0	100
C	27.7	25.8	42.0	95.5	0.0	0.0	0.2	0.2	0.5	0.2	1.9	2.6	0.7	0.0	0.5	1.2	0.0	0.0	0.5	0.5	100
D	10.0	23.8	60.7	94.5	0.0	0.0	0.0	0.2	1.0	0.2	2.0	1.4	0.6	0.2	0.2	1.0	0.0	0.0	1.3	1.3	100
E	73.8	18.4	1.2	93.4	0.0	0.0	0.0	0.0	2.8	1.2	1.2	5.2	0.6	0.2	0.4	1.2	0.0	0.0	0.2	0.2	100
F	84.7	10.6	0.5	95.8	0.9	0.2	0.0	1.1	0.7	1.2	0.0	1.9	0.7	0.0	0.0	0.7	0.3	0.0	0.2	0.5	100
G	4.3	5.3	83.0	92.6	0.0	0.0	0.3	0.3	1.0	3.4	1.7	6.1	0.3	0.2	0.5	1.0	0.0	0.0	0.0	0.0	100
H	10.8	5.7	77.7	94.2	0.0	0.0	0.0	0.0	3.0	1.2	0.2	4.4	0.6	0.0	0.4	1.0	0.0	0.0	0.4	0.4	100
I	2.4	2.3	82.0	86.7	0.0	0.0	0.0	0.0	0.2	0.5	10.0	10.7	0.4	0.0	2.0	0.6	0.0	0.0	0.2	0.2	100
J	4.9	3.7	79.6	88.2	0.0	0.0	0.3	0.3	0.8	0.5	7.6	8.9	0.1	0.0	2.5	3.5	0.0	0.0	0.0	0.0	100

*K = killed; D = damaged or injured, and H = healthy or unaffected.

[@]For explanation of treatments please refer to Table 1.

Table 3. Average number (based on actual counts) of broadleaf weeds per plot per treatment in the experimental plots at Manhattan, net plot size 51' x 6'.

Treat- ment@	Ambrosia			Solidago			Amorpha			Liatrus			Helianthus		
	K	D	H	K	D	H	K	D	H	K	D	H	K	D	H
A	0.5	0.5	6.5	9.3	9.8	2.3	1.5	12.3	11.0	0.5	9.3	21.3	0.0	2.3	1.8
B	2.0	0.0	0.5	27.8	7.8	0.0	1.8	2.5	19.8	2.8	3.0	12.0	0.3	0.0	0.0
C	25.8	0.5	15.0	33.5	28.8	2.3	1.3	10.0	3.3	4.5	15.3	6.0	1.3	0.3	0.0
D	11.3	0.3	1.5	14.5	8.5	1.0	1.3	8.0	1.5	14.0	12.8	14.0	0.3	0.3	0.0
E	8.5	0.0	2.0	11.3	54.0	4.8	4.3	0.0	0.3	5.8	4.3	0.0	2.5	43.3	4.0
F	17.3	0.0	0.8	23.8	48.0	0.0	0.3	0.0	0.0	8.5	1.5	0.0	0.8	8.0	4.3
G	15.8	58.0	16.5	3.0	49.3	7.5	0.0	1.0	0.0	4.5	14.5	61.5	0.8	2.3	14.3
H	12.3	11.3	0.3	16.0	35.0	0.0	3.0	0.0	0.0	1.3	13.0	4.0	0.3	7.0	0.5
I	0.0	0.0	570.0	0.0	0.0	165.0	0.0	0.0	0.0	0.0	0.0	230.0	0.0	0.0	145.0
J	0.0	0.0	732.5	0.0	0.0	120.0	0.0	0.0	25.0	0.0	0.0	65.0	0.0	0.0	187.5

*K = killed; D = damaged or injured, and H = healthy or unaffected.

@For explanation of treatments please refer to Table 1.

Table 4. Botanical composition of the experimental plots at Lebo, as determined by line transect method, The data is arranged treatmentwise (herbicidal treatments).

	Percentage composition																	Total vegetation
	Perennial grasses				Annual bromegrass	Perennial forbs				Annual and biennial forbs				Carex and Juncus				
Tr.[@]	K[*]	D	H	% of vegn.	% of vegn.	K	D	H	% of vegn.	K	D	H	% of vegn.	K	D	H	% of vegn.	%
A	0.8	0.0	6.2	7.0	79.4	2.0	0.6	9.0	11.6	0.0	0.0	0.2	0.2	0.0	0.0	1.8	1.8	100
B	0.0	0.1	8.2	8.3	80.8	0.5	3.7	1.2	5.4	0.3	0.0	0.0	0.3	0.1	0.0	5.1	5.2	100
C	0.3	0.2	4.7	5.2	75.0	1.6	0.8	15.6	18.0	0.0	0.0	0.3	0.3	0.0	0.0	1.5	1.5	100
D	0.1	0.0	0.6	0.7	83.2	0.3	0.2	10.6	11.1	0.2	0.0	2.0	2.2	0.0	0.0	2.8	2.8	100
E	1.5	0.4	2.0	3.9	94.0	1.3	0.0	0.2	1.5	0.0	0.0	0.0	0.0	0.2	0.0	0.4	0.6	100
F	2.0	0.7	0.3	3.0	95.0	1.0	0.0	0.0	1.0	0.0	0.0	0.3	0.3	0.2	0.0	0.5	0.7	100
G	0.0	0.0	1.4	1.4	77.0	1.0	0.3	12.8	14.1	0.0	0.0	1.0	1.0	2.0	0.5	4.0	6.5	100
H	0.1	0.2	10.0	10.3	81.8	0.6	1.4	1.3	3.3	0.0	0.0	0.9	0.9	0.0	0.3	3.4	3.7	100
I	0.2	0.0	2.6	2.8	81.4	1.2	0.0	11.0	12.2	0.0	0.3	0.3	0.6	0.0	0.0	3.0	3.0	100
J	0.0	0.0	7.0	7.0	70.0	1.7	0.0	17.0	18.7	0.0	0.0	0.3	0.3	0.0	0.0	4.0	4.0	100

[*]K = killed; D = damaged or injured, and H = healthy or unaffected.

[@]For explanation of treatments please refer to Table 1.

Table 5. Average number (based on actual counts) of broadleaf weeds per plot per treatment in the experimental plots at Lebo. Net plot size 51' x 6'.

Treatment[@]	Ironweed K*	Ironweed D	Ironweed H	Rumex K	Rumex D	Rumex H	Miscellaneous Total No.
A	36.5	0.0	11.5	4.0	0.0	0.8	108.0
B	36.5	0.0	3.0	4.3	0.0	0.0	48.0
C	37.0	0.0	4.0	3.0	0.0	0.3	64.0
D	44.5	0.0	0.8	9.5	0.0	0.0	44.5
E	33.0	0.0	0.0	3.0	0.0	0.0	77.0
F	41.0	0.0	0.0	5.0	0.0	0.0	64.0
G	13.0	0.0	22.0	4.0	0.0	2.0	60.5
H	34.0	0.0	13.0	8.0	0.0	0.3	63.0
I	1.5	0.0	45.0	0.0	0.0	5.0	53.0
J	0.0	0.0	48.0	0.3	0.0	2.3	81.0

*K = killed; D = damaged or injured, and H = healthy or unaffected.
[@]For explanation of treatments please refer to Table 1.

consisted mainly of western ragweed (Ambrosia psilostachya) stiff goldenrod (Solidago rigida), Amorpha spp., Liatris, and Helianthus spp.

At Lebo (Table 4) perennial grasses were in negligible amounts and consisted of tall dropseed (Sporobolus asper) Kentucky bluegrass (Poa pratensis), Scribner panicum, and switchgrass (Panicum virgatum). There was a predominance of annual brome (Bromus spp.). This brome had completed its life cycle at the time when herbicides were applied. Broadleaf weeds (Table 4) consisted of ironweed (Vernonia baldwini), curled dock (Rumex crispus) and miscellaneous spp. such as Trifolium, Ambrosia, Ruellia, and Artemesia.

Effects of Herbicidal Treatments on Different Groups of Vegetation Present in the Experimental Plots

Tables 2 and 4 give a very general idea of the effectiveness of the various herbicides. Reference to Table 2 shows that erbon (E and F treatments) killed all classes of plants to a considerable degree. Treatments C and D have injured the grasses considerably. Treatments A, B, G, and H appear to have affected perennial forbs to a considerable extent when injured and killed classes are combined, as compared with other treatments. In Table 4 which refers to Lebo, treatments, except E and F, have not killed or damaged grasses in significant amounts.

Effects of Herbicidal Treatments on Broadleaf Species Present in the Experimental Plots

Reference to Table 3 shows Ambrosia to be very susceptible to almost all the treatments, whereas other species have been damaged considerably. At Lebo (Table 5) ironweed and curled dock have been killed in significant amounts by most of the herbicidal treatments.

Statistical analysis of the data presented in Tables 2 through 5 could not be made because of considerable differences in the density of different species of weeds in different parts of the experimental areas.

Efficacy of the Herbicidal Treatments Based on the Quantity of Residues of Weeds Killed by Herbicides

Results of the quadrat clippings were analyzed, and the analysis of variance based on the percent dry matter after treatments have been presented in Table 6.

The treatments are arranged in descending order of efficacy compared

to the check 'I' in killing vegetation of the experimental plots as shown in Table 7.

Table 6. Analysis of variance on percent dry matter after treatments. Location--Manhattan.

Sources of variation	d.f.	Ms.	F.	Sig.
Replications	3	57.6275		
Treatments	8	8281.3495	55.19	***
R x T	24	150.0478	1.02	n.s.
Error	71	146.8521		

L.S.D. = 9.842.

Table 7. Descending order of the treatments showing the efficacy of the treatments.

Treatments*:	F	E	C	D	H	B	A	G	I	J
Means	98.6	84.58	69.54	47.2	34.3	27.11	25.508	13.04	12.258	10.95

*For explanation of treatments please refer to Table 1.

H, B, and A treatments are of the same magnitude, as are treatments G, I, and J. Most of the treatments have shown significant differences in their killing action. The choice of any one or more chemicals would depend, apart from the cost, on the lesser residual effects in the soil.

Germination Tests of the Seeds of Grass Species Intended for Seeding Experimental Flats and Plots

The number of seedlings that would establish finally in the field would depend upon the inherent germinating capacity of the seeds, the residual effects of the treatments left in the soil, and the effects of the

weed residues. Germination tests of grass seeds were taken to adjust the seed rates. The results of the tests are presented in Table 8.

Table 8. Germination tests of the grass seeds intended for sowing experimental plots and flats.

	Species	I set	II set	III set	Ave. percentage
1	Timothy	91	90	92	91.0
2	Orchardgrass	62	70	52	61.3
3	Kentucky fescue	100	98	97	98.3
4	Western wheatgrass	30	43	31	34.6
5	Southland brome	74	77	83	78.0
6	Reed canarygrass	21	27	25	24.3
7	Intermediate wheatgrass	79	83	81	81.0
8	Big bluestem	56	53	58	55.6
9	Indiangrass	20	19	12	17.0
10	Sand lovegrass	57	66	69	64.0
11	Woodward sand bluestem	13	21	18	17.3

Residual Effects of Herbicides on the Germination of Seeds of Eleven Species of Grasses in Flats

Data on the germination of seeds in flats placed in the greenhouse were analyzed statistically and the treatments which caused significantly less germination compared to check 'I' have been presented in Tables 9 and 10 for Manhattan and Lebo locations, respectively. Significance was based on a chi square tests of independence.

Table 9. Treatments which caused significantly less germination of seeds compared to the check 'I'. Soil from Manhattan location.

	Species	Treatments which caused significantly less germination
1	Timothy	B C E F G H*
2	Orchardgrass	C D
3	Kentucky fescue	A D G
4	Western wheatgrass	G
5	Southland brome	C E G
6	Reed canarygrass	A C
7	Intermediate wheatgrass	--
8	Big bluestem	--
9	Indiangrass	A C D
10	Sand lovegrass	D
11	Woodward sand bluestem	B C D E G

*For explanation of treatments please refer to Table 1.

Table 10. Treatments which caused significantly less germination of seeds compared to the check 'I'. Soil from Lebo location.

	Species	Treatments which caused significantly less germination
1	Timothy	C E F H*
2	Orchardgrass	H
3	Kentucky fescue	—
4	Western wheatgrass	—
5	Southland brome	E
6	Reed canarygrass	A C E D G H
7	Intermediate wheatgrass	B D
8	Big bluestem	—
9	Indiangrass	F B H C D
10	Sand lovegrass	B F D
11	Woodward sand bluestem	D G

*For explanation of treatments please refer to Table 1.

The above species were seeded four months after application of the treatments. It appears therefore that all treatments leave toxic residual effects in soil at least up to four months. Furthermore, the different species of grasses show differential response to the residual effects of herbicidal treatments. Since treatments C and D have affected majority of grass species, it appears that these two treatments may be leaving residual effect for more than four months.

Residual Effects of Herbicides on the Seedling Height of Eleven Species of Grasses

Statistical analysis of the data revealed that the differences in

height of plants were not significant for all treatments and for all the eleven species of grasses tested. It shows therefore that development of plants seeded four months after application was not affected by the residues of the herbicides.

DISCUSSION

It is apparent from the results that different species show differential response to the residual effect of chemical treatments. Work of Kates et al. (8), Rogers and Hart (15), Appleby (4), Parsons (11), also tended to show that the residual effect of dalapon lasted from five days to over two months, depending upon the crops sown. Since this is the case, it is necessary to wait until all the residual effects are dissipated or else after a reasonable period of time plant species which might be tolerant. However, too great a delay in seeding would permit weed seeds to germinate and present a new weed problem as stated by Sprague (20). It is therefore advisable to select species to suit the chemicals or vice versa. Looking at the overall results of the residual effects after a period of four months following application of herbicides, it appears that treatments 2,4-D at 1 pound and 2 pounds per acre and erbon at 1/2 pound and 1 pound per square rod can well be used for creating a mulch of weeds, since a majority of the grasses seeded in flats were not affected by the residual effects of these chemicals. Treatments C and D (2,4-D + dalapon two concentrations) appeared to be toxic to more than five species out of 11. This apparently shows that concentrations of these chemicals in the soils were greater compared with other treatments, even after a period of four months following the applications. Treatments G and H (2,3,6-TBA) showed variable results.

If complete kill is required, erbon appears to offer promise, but if cost becomes prohibitive treatments A and B (2,4-D two concentrations) would serve the purpose satisfactorily without disturbing the germinating ability of a majority of the desirable grass species. Some species (Tables 9 and 10) such as Kentucky fescue, Southland smooth brome, and indiangrass, have shown susceptibility to lower concentrations of some chemicals and tolerance to higher concentrations of the same chemicals. Such erratic behavior may be the result of uneven depth of soil, differences in density of vegetation in different parts of the experimental area, and to kind of vegetation. Since native ranges are usually undulating and oftentimes rough and stony, such erratic results may frequently be expected. Under these circumstances large number of replications with smaller plot size may offer more accurate information.

It is to be noted that, whereas the development of plants (as judged by height) is not affected due to residues of herbicides in the soil, there is a distinct effect on the germination of grass seeds. It seems, therefore, that higher seed rates may compensate for the losses in germination of seeds caused by the residual effects of herbicides in the soil.

SUMMARY

Based on the experimental results, it was found that:

(1) the herbicidal treatments could be arranged with respect to their efficacy in killing the vegetation, in the following descending order: (a) erbon, 1/2 lb/sq rod; (b) erbon, 1 lb/sq rod; (c) 2,4-D, 2 lbs/acre + dalapon, 8 lbs/acre; (d) 2,4-D, 4 lbs/acre + dalapon, 4 lbs/acre; (e) 2,3,6-TBA 16 lbs/acre; (f) 2,4-D, 4 lbs/acre; (g) 2,4-D, 2 lbs/acre; (h) 2,3,6-TBA

8 lbs/acre.

(2) Different species of grasses react differentially to the residual effects left by various chemical treatments.

(3) All chemical treatments leave residual effects in the soil for at least four months. However, 2,4-D and erbon treatments appear to show less toxicity compared to 2,4-D + dalapon (2 lbs + 8 lbs/acre respectively) and 2,4-D + dalapon (4 lbs + 4 lbs/acre respectively). 2,3,6-TBA treatments showed variable results.

(4) Timothy, indiangrass, sand bluestem, reed canarygrass appeared to be very susceptible to the residual effects of the majority of herbicidal treatments tested. Big bluestem was found to be tolerant to all the herbicidal treatments.

(5) Height of plants of the grasses was not affected by the residual effects of the herbicidal treatments four months after application.

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STUDIES RELATING TO SEEDING DEPLETED RANGE IN UNDISTURBED RESIDUES OF WEEDY VEGETATION KILLED BY HERBICIDES

by

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Deterioration of grassland is caused by overgrazing year after year. If excessive removal of desirable vegetative growth from grasslands is continued the desirable pasture plants are gradually eliminated and replaced by an abundance of weeds. Renovation of such rundown grasslands is a long and costly process. The problem of seedbed preparation on native ranges is difficult, since they are often steep and may be physically impossible to till. Further, tillage operations under such conditions would be conducive to more erosion and may result in further deterioration of the already depleted grasslands. The objective of the work presented in this thesis was to learn whether depleted range could be prepared for seeding in undisturbed residues of weedy vegetation killed by herbicides. The objective of using herbicides was to create a dead mulch of the existing vegetation attached on to an undisturbed soil surface. Living weeds otherwise would compete with new seedings. Further, the evenly distributed surface mulch of dead plant material would function well for soil and water conservation. Elimination of tillage leaves a firm seedbed in which deeply buried weed seeds are not disturbed. Such a mulch also helps keep soil surface moist and cool.

Weedy pastures were selected at two locations; one near Lebo about 100 miles southeast of Manhattan and the other about seven miles northwest of Manhattan. At each location a randomized replicated trial was laid out using the following ten treatments:

A.	2,4-D L. V. ester	2 lbs/acre
B.	2,4-D L. V. ester	4 lbs/acre
C.	2,4-D + Dalapon	2 lbs + 8 lbs/acre
D.	2,4-D + Dalapon	4 lbs + 4 lbs/acre

E.	Erbon	1/2 lb/square rod
F.	Erbon	1 lb/square rod
G.	2,3,6-TBA	8 lbs/acre
H.	2,3,6-TBA	16 lbs/acre
I.	Check	
J.	Check	

Information on the following items was collected from field and greenhouse studies:

(1) Botanical composition of each individual plot was determined, following the herbicidal treatments, by the line-transect method.

(2) While obtaining the above data, counts of the numbers killed, injured or unaffected were recorded.

(3) Quadrat (4.356 sq. ft.) clippings were made from all treatment plots to determine the efficacy of the chemical treatments. It was assumed that the more effective the kill of the herbage the less would be the weight of the residue clipped from each quadrat when compared to quadrats clipped from check plots.

(4) Flats (1'x 2') were filled with soil from the surface 3" of each plot and each flat was sown to 11 species of grasses for studying the residual effects of treatments. The exact number of seeds for sowing was determined on the basis of germination studies. It was desired to establish 50 seedlings per foot row. It was assumed that if the number of seedlings of a species in any flat happened to be smaller than the number of seedlings of the corresponding species in check flats, the deficit was to be ascribed to the residual effect of the herbicide in the soil in such flat.

(5) Average height of seedlings of each species in each flat was recorded to determine if development (as judged by height) was affected by